In compliance with the
Canadian Privacy Legislation
some supporting forms
may have been removed from
this dissertation.

While these forms may be included
in the document page count,
their removal does not represent
any loss of content from the dissertation.

University of Alberta

Factors Associated with Spinal Cord Injuries Among Drivers

By

Dianne Kirwin

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Science

Medical Sciences – Public Health Sciences

Edmonton, Alberta
Fall 2003

National Library of Canada
Bibliothèque nationale du Canada

Acquisitions and Bibliographic Services
Acquisisitons et services bibliographiques

395 Wellington Street
Ottawa ON K1A 0N4
Canada

395, rue Wellington
Ottawa ON K1A 0N4
Canada

Your file Votre référence
ISBN: 0-612-87802-3
Our file Notre référence
ISBN: 0-612-87802-3

The author has granted a non-exclusive licence allowing the National Library of Canada to reproduce, loan, distribute or sell copies of this thesis in microform, paper or electronic formats.

L'auteur a accordé une licence non exclusive permettant à la Bibliothèque nationale du Canada de reproduire, prêter, distribuer ou vendre des copies de cette thèse sous la forme de microfiche/film, de reproduction sur papier ou sur format électronique.

The author retains ownership of the copyright in this thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without the author's permission.

L'auteur conserve la propriété du droit d'auteur qui protège cette thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou aturement reproduits sans son autorisation.

Canada

University of Alberta

Library Release Form

Name of Author: Dianne L. Kirwin

Title of Thesis: Factors Associated with Spinal Cord Injuries Among Drivers

Degree: Master of Science

Year this Degree Granted: 2003

Permission is hereby granted to the University of Alberta Library to reproduce single copies of this thesis and to lend or sell such copies for private, scholarly or scientific research purposes only.

The author reserves all other publication and other rights in association with the copyright in the thesis, and except as herein before provided, neither the thesis nor any substantial portion thereof may be printed or otherwise reproduced in any material form whatever without the author's prior written permission.

Date: September 29/03

University of Alberta

Faculty of Graduate Studies and Research

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled Factors Associated with Spinal Cord Injuries Among Drivers submitted by Dianne Kirwin in partial fulfillment of the requirements for the degree of **Master of Science**.

Dr. Linda Carroll
Supervisor

Dr. Richard Fox

Dr. Ambikaipakan (Sentil) Senthilselvan

Dr. Duncan Saunders

Date: Sept 29, 2003

Abstract

Trauma registry data was used to examine factors associated with the occurrence of spinal cord injuries among seriously injured drivers hospitalized between April 01, 1995 and March 31, 2001 due to a motor vehicle collision. There were 1753 seriously injured drivers; 117 (7%) had spinal cord injury and 1636 (93%) did not. The most important factor associated with spinal cord as opposed to other serious injuries was single vehicle rollover collisions (adjusted OR 6.59, 95% CI 4.00 – 10.85). When the effects of age, vehicle type, and roadway are adjusted for, male drivers are almost twice as likely as females to be involved in a single vehicle rollover collision (adjusted OR 1.62, 95% CI 1.27-2.08). This study indicates that single vehicle rollover collisions are strongly associated with the occurrence of spinal cord injuries after a passenger vehicle collision. Single vehicle rollover collisions are more common among males, pickup truck drivers and on rural roadways.

Acknowledgements

I would like to express my profound gratitude to my supervisor, Dr. Linda Carroll who provided excellent and patient mentoring. This thesis would not exist without her help.

I am also very grateful to my thesis committee members, Dr. Richard Fox and Dr. Senthilselvan for their valuable suggestions that improved my dissertation.

I would also like to thank Dr. Duncan Saunders and Dr. Colin Soskolne who participated in my thesis exam.

Lastly and mostly, I would like to thank Mark, Scooter, Kirby, and Rachel who kept me happy and motivated so that I could graduate.

Table of Contents

		page
Chapter 1		
Introduction		1
1.1	Statement of The Problem	1
1.2	Research Question	3
Chapter 2		
Review of the Literature		6
2.1	Literature Search Strategy	6
2.2	Seatbelts	7
2.3	Ejections	10
2.4	Collision Type	11
2.5	Age	12
2.6	Gender	13
2.7	Literature review Summary	14
Chapter 3		
Methodology		18
3.1	Study Design	18
3.2	Inclusion Criteria	18
3.3	Case Definitions	19
3.4	Trauma registry Data	20
3.5	Selection Filters	25
3.5	Explanatory Factors	26
3.6	Data Preparation	26
3.7	Assessing Interactions	28
3.8	Ethics	29
Chapter 4		
Results		30
4.1	Age	33
4.2	Gender	33

4.3	Place of residence & place of injury	34
4.4	Time , Day and Month of Injury	35
4.5	Alcohol Use	37
4.6	Seatbelts	37
4.7	Type of Crash	38
4.8	Vehicle Type	39
4.9	Types of Injuries	40
4.10	Factors associated with spinal cord injury- Logistic regression results	41
4.11	Stratified Analysis	44
4.12	Factors associated with Single vehicle Rollovers	46
Chapter 5		48
	Discussion	48
	Conclusions	55
	Recommendations	55
REFERENCES		56
APPENDIX I		70

List of Tables

		page
Table 1:	Summary Findings from Studies of Motor Vehicle Related Spinal Cord Injury	16
Table 2:	Alberta 1995-2001: Hospitalization For Spinal Cord Injury Among Drivers Of Passenger Vehicles Injured During A Motor Vehicle Collision-Total Number By Gender And Hospitalization Rate Among Residents Of Alberta	31
Table 3:	Characteristics Of Drivers Of Passenger Vehicles Who Were Seriously Injured And Hospitalized After A Motor Vehicle Collision	32
Table 4:	Numbers of Types of Spinal Cord Injuries by ICD9 Code	40
Table 5:	Univariate Logistic Regression Results Describing Factors Associated with Occurrence of Spinal Cord Injuries Among Seriously Injured Drivers	42
Table 6:	Multivariable Logistic Regression Results Describing Factors Associated with Occurrence of Spinal Cord Injuries among seriously injured drivers	44
Table 7:	Stratified Analysis: Logistic Regression Results Describing Factors Associated with Occurrence of Spinal Cord Injury	46
Table 8:	Multivariable Logistic Regression Results Describing Factors Associated With Occurrence of Single Vehicle Rollover Collisions	47

List of Figures

		Page
Figure 1:	Selection Filters In Effect for the Study Sample	25
Figure 2:	Seriously Injured Drivers with Spinal Cord Injury: Distribution by Age at Injury	34
Figure 3:	Seriously Injured Drivers with Spinal Cord Injury: Time of Injury	35
Figure 4:	Seriously Injured Drivers with Spinal Cord Injury: Day of Week Injury	36
Figure 5:	Seriously Injured Drivers with Spinal Cord Injury: Month of Injury	36

Chapter 1. Introduction

Statement of the problem

Within the spectrum of physical injuries, those to the spinal cord are among the most profoundly devastating and least reversible forms of trauma. People with spinal cord injury can suffer permanent loss of sensation, movement, bladder and bowel control and sexual function. Spinal cord injuries may result from a traumatic insult to the spine resulting in a temporary or permanent change in its normal motor, sensory, or autonomic function. Mechanisms of spinal cord injury include direct trauma, mechanical compression/ disruption of the spinal cord by disk or bone fragments, hematomas, and/or ischemia from damage to spinal arteries (Young, 2002). Any one or a combination of these mechanisms can cause total or partial loss of motor and/or sensory function below the site of injury. Injury to the thoracic, lumbar or sacral regions may cause paraplegia/paresis, whereas cervical injuries are associated with quadraplegia and even respiratory dependence and death (Young, 2002). In addition, chronic pain causes an enormous burden of suffering among spinal cord injury survivors (Finnerup 2001, Ravenscroft, 2000).

Among Albertans, using data sources that allowed identification of both pre-hospital fatalities and hospitalizations for spinal cord injury, the estimated spinal cord injury incidence rate is 58 per million population per year (Dryden, 2002). In Canada in 1998/99 there were 1347 people hospitalized with spinal cord injury conferring an annual incidence rate of 45 hospitalizations for spinal cord injury per million population (Canadian Institute of Health Information, 2001). American studies report estimates of annual rates for hospitalizations for spinal cord injury that range from 25 to 59 cases per

million population (Woodruff ,1994; Bracken, 1981; Price,1994; Thurman,1994; Surkin, 1998). In the U.S., estimates of the annual incidence of spinal cord injury that include both hospitalizations and pre-hospital fatalities range from 51 to 78 cases per million population (Griffin, 1985; Price, 1994; Surkin, 1998). Differences in the incidence rates are likely due to variation in the case definitions and completeness of the data sources used to identify spinal cord injury.

There are no conclusive data regarding the prevalence of spinal cord injury in Canada. The Canadian Paraplegic Association estimates that, based on extrapolation from American data, approximately 36,000 Canadians live with spinal cord injury (Canadian Paraplegic Association, 2000). Given a population of approximately 31 million people (Statistics Canada, 2002), the prevalence of spinal cord injury in Canada is estimated to be 1145 cases per million population. In the U.S., estimates of the prevalence of spinal cord injury range from 200,000 to 250,000 cases (DeVivo, 1980; Ergas, 1985; Lasfargues, 1995). Given a population of approximately 281 million people (United States Census Bureau, 2003), the prevalence of spinal cord injury in the United States is estimated to between 727 to 909 cases per million population.

The leading causes of spinal cord injuries are motor vehicle related, followed by falls, violence and sports/recreation (Minaire, 1978; Bracken, 1981; Fine, 1982; Danesh, 1991; Dixon, 1993; Woodruff, 1994; Sekhon, 2001; O'Connor, 2002). Canadian data from 1998/99 shows that among people hospitalized for spinal cord injury, 43% of spinal cord injuries occurred as a result of transportation mishaps (Canadian Institute of Health Information, 2001). American studies report that 40 to 69% of hospitalizations for spinal cord injury are due to motor vehicle transportation causes (Burney, 1993; Griffin, 1985;

Price, 1994; Woodruff, 1994). From data spanning three decades, the more recently injured people with spinal cord injuries are younger, have less severe cord injury and are more often injured in motor vehicle collisions (Tator, 1993).

Since the late 1940's, there has been research into the role of the driver in highway crashes (Waller, 1994). Over five decades of study has resulted in a significant body of literature regarding risk factors for involvement in serious and fatal collisions. From this literature, it is evident that factors such as drinking alcohol prior to driving (Andersen, 1990; Perenger, 1991; Ostrum, 1995; Sommers, 2000), speeding (Mao, 1997; Norris, 2000) younger age (Norris, 2000) prior motor vehicle collisions (Perenger, 1991; Norris, 2000) and driver sleepiness (Connor, 2002) are associated with a greater likelihood of being involved in a serious or fatal collision.

Furthermore, the ever-increasing body of literature demonstrates that there is significant overlap between high-risk driver behaviors. For example, compared to drivers who use seatbelts, drivers who do not use seatbelts are twice as likely to be legally impaired while driving (Foss, 1994). The link between speeding and non-use of seatbelts is also well established, with drivers who exceed posted speed limits showing lower belt use rates (Preusser, 1988).

In the literature, much less attention has been paid to factors associated with spinal cord injury among surviving drivers of serious car crashes. Many of the factors associated with the occurrence of serious and fatal crashes have been well elucidated and described, yet, once the crash has occurred, factors that contribute to spinal cord injuries among drivers have not been as well described. This literature is reviewed in the next section. The main research question addressed in this thesis is: "What factors are

associated with the occurrence of spinal cord injuries, as opposed to other serious injuries among drivers of passenger vehicles (cars, sport utility vehicles and light trucks), injured in motor vehicle crashes who survive long enough to be admitted to a trauma center?"

This study used a dataset provided by the provincial trauma registry. In Alberta, hospital based trauma registries located in the four designated tertiary trauma centers submit trauma patient data to a centralized trauma registry. As such, the provincial trauma registry provides a means of collecting detailed injury data on a large number of seriously injured patients treated in Alberta's designated tertiary trauma centers. The provincial (centralized) trauma registry submits data to the national trauma registry. Trauma registries have been an important source of patient data regarding the epidemiology and outcomes of serious injuries for over thirty years.

The need for trauma registries was first mentioned in the 1969 report, Accidental Death and Disability: The Neglected Disease of Modern Society (National Academy of Science National Research Council, 1969). Since the first reported use of a computerized state-wide trauma registry in 1970 in Illinois (Goldberg, 1980), trauma registries have proliferated. Presently, in Canada, a trauma registry is a required component for trauma center accreditation (Trauma Association of Canada, 1993). The history and development of trauma registries in Canada is described by McLellan (McLellan, 1997). In general terms, trauma registries are computerized, standardized collections of patient data centered on traumatic injury events that meet or exceed a specified severity threshold. The primary purpose of a trauma registry is to provide data that allows for the evaluation of the quality of trauma care and outcomes in individual institutions and in trauma systems (Pollock, 1989). The secondary purpose of registries is to provide data

for injury surveillance activities such as research, development, implementation and evaluation of injury control initiatives (Pollock, 1989).

Chapter 2. Review of the Literature

Literature Search Strategy

To identify background information, a broad search strategy was used. A literature search was conducted on Medline, UMI Dissertation Abstracts, and the Internet. The Medline database was searched for the years 1966 – 2002 using the following text words: spinal cord injury, cervical injury, axis-fracture, neck, c-spine, car crash, collision, car, automobile, pick-up truck, rollover, ejection, epidemiology, and traffic accidents and MeSH terms: Accidents, Traffic; Automobiles; Motor Vehicles; Multiple Trauma; Risk Factors; Seat Belts and Spinal Cord Injuries. A study was considered relevant if it examined spinal cord injuries that occurred during a passenger vehicle crash. In addition, major authors in this topic area were identified and other relevant publications by those authors were searched for. In order to find citations that were not identified through the text word and MESH searches, author searches were done for the following authors: Cushman LA, Hadley MN, Huelke DF, O'Connor P, Sasso RC, Tolonen J, Thurman DJ and Wigglesworth EC. These authors were included in an author search because they were identified as having written at least one article specifically about motor vehicle related spinal cord injury.

The UMI Dissertation Abstracts database was also searched using the term 'spinal cord injury'. The Google and MSN Search engines were used to search the internet for information about spinal cord injuries and car crashes. Key injury related Websites were identified and searched: Spinal cord injury Information Network (http://www.spinalcord.uab.edu), SafetyLit (http://www.safetylit.org), National Highway Traffic Safety Administration (http://www.nhtsa.dot.gov), National Centre for Injury

Prevention and Control (http://www.cdc.gov/ncipc), Health Canada (http://www.hc-sc.gc.ca), Alberta Motor Association (http://www.ama.ab.ca/trafsafe/mission.htm), Traffic Safety in Alberta http://www.saferoads.com/), Alberta Infrastructure (http://www.tu.gov.ab.ca), Harvard Injury Control Center (http://www.hsph.harvard.edu/hicrc), The Harborview Injury Prevention and Research Center (http://depts.washington.edu/hiprc), Injury Prevention Web (http://www.injurypreventionweb.org) and the Australia National Injury Surveillance Unit (http://www.nisu.flinders.edu.au). Key journals were hand searched back five years from July 2002. Journals searched were Paraplegia, Spine, The Journal of Trauma, Neurosurgery and the Journal of Neurosurgery. The above strategy yielded 78 citations that were relevant to the research question, and are used in this thesis to provide background information.

Of the papers that were relevant to the thesis research question, eight studies specifically dealt with the occurrence of spinal cord injury during a car crash (Huelke, 1981; Hadley, 1986; Tolonen, 1986; Cushman, 1991; Wigglesworth, 1992; Thurman, 1995; Sasso, 1997; O'Connor, 2002). The findings from these studies are summarized in Table 1. The main factors identified in the literature search were age, gender, seatbelt use, collision type and whether or not the person was ejected from the vehicle during the crash. Therefore, the literature review focused on these factors.

Seatbelts

Seatbelt use has been consistently documented to decrease mortality and injury severity among occupants involved in motor vehicle crashes (Orsay, 1988). Research by the U.S. Department of Transportation, National Highway Traffic Safety Administration

has found that use of seatbelts (lap/shoulder safety belts) among front-seat car occupants is associated with 45% and 50% reduction in fatal injuries and moderate-to-critical injuries respectively (National Highway Traffic Safety Administration, 2002). The effectiveness of seatbelts is more pronounced for light truck occupants; use of seatbelts in these vehicles reduces the risk of fatal injury by 60% and moderate-to-critical injury by 65% (National Highway Traffic Safety Administration, 2002)

Kaplan and Cowely used a random sample of seriously injured drivers and studied the effects of seatbelt use on severity of injury. They found that the use of seatbelts was associated with a 34% reduction in the total number of injuries among drivers admitted to hospital (Kaplan, 1991). Major injuries were decreased by 57% and minor injuries by 20%. Unbelted drivers had a mean Injury Severity Score that was twice as great as the belted drivers and were hospitalized 1.6 times longer at double the cost (Kaplan, 1991). The authors concluded that major injuries to the face, chest, and pelvic regions were prevented by using seatbelts (Kaplan, 1991). In a Canadian study of drivers hospitalized due to motor vehicle collisions, belted drivers had significantly lower mean length of stay and lower Injury Severity Scores than the non-belted drivers (Andersen, 1990).

The literature demonstrates that use of seatbelts among motor vehicle occupants decreases the rate of spinal cord injury and the extent of neurologic injury among those who sustain a spinal cord injury in a motor vehicle crash (Huelke, 1981; Sasso, 1997). In a study of 1352 patients with spinal cord injury as a result of a car crash, the odds of an intact spinal cord injury (vs. non-intact) were 1.6 times greater for belted versus non-belted occupants (Sasso, 1997). Sasso used the American Spinal Injury Association's standards for classification of the extent of neurologic injury and, according to this

definition, an intact injury retains some sensory or motor function in sacral segments 4 and 5.

Huelke's examination of data from over 10,000 vehicle occupants injured in tow-away crashes concluded that almost all serious and fatal cervical injury occurred among people who were not wearing a seatbelt (Huelke, 1981). In this study, 84% of the injured people were documented as not wearing a seatbelt and only 6% of the occupants were documented as wearing a seatbelt at the time of the crash. For the remaining cases, seatbelt use at the time of the crash was not known (Huelke, 1981).

One of the ways that seatbelts exert a protective effect against neurologic injury during a car crash is by keeping the occupant inside a vehicle during the crash. Among a group of drivers not wearing a seatbelt, Hadley found that people who were thrown from their vehicle had nearly twice the rate of cervical spine injuries (31% versus 18%) than those who were not ejected during the crash (Hadley, 1985). Hadley also found that among occupants with axis fractures who were not wearing a seatbelt at the time of injury, 73% (21/29) had associated severe head injuries or other cervical injury.

Bourbeau and colleagues studied 3927 injured front-seat occupants (drivers and passengers) who were injured in car crashes in which two vehicles were involved. They found that 725 front-seat occupants sustained minor neck sprains (ICD-9 code 847.0) and that serious injuries to the cervical spine were more common among the unbelted occupants. They report that belted victims had a three fold lower rate of cervical fracture (Bourbeau, 1993).

Invariably, these studies document a low rate of seatbelt use among people who suffered a spinal cord injury as a result of a motor vehicle collision.

Ejections

Car crash studies suggest that ejection from the vehicle is one of the most important determinants of serious and fatal central nervous system injuries. Among occupants ejected from passenger cars during a crash, 75% are killed (National Highway Traffic Safety Administration, 2002). Data from the Fatal Analysis Reporting System shows that while occupant ejections are an infrequent event, occurring during only 0.8% of motor vehicle collisions, they were associated with 27% of deaths (National Highway Traffic Safety Administration, 1999). Data from studies that controlled for crash severity suggest that passengers who are ejected from cars are four times more likely to die from their injuries than those who were not ejected (Malliaris, 1996; Scheidler, 2000).

Huelke's study of 10,151 occupants injured in tow-away crashes found a 36-fold increase in serious or fatal cervical injuries among people who were ejected from the vehicle. This study revealed that for people who were not ejected from the vehicle at the time of the crash, only 0.2% had a serious or fatal cervical injury versus 7.2% for occupants who were ejected (Huelkle, 1981).

Other studies have also shown much higher rates of serious injury to the head and neck among occupants ejected from their vehicles during a crash (Gongora, 2001). Gongora and colleagues also noted that a higher proportion of ejected patients were male and were younger than those injured in serious crashes but not ejected from their vehicle. In Gongora's study, the male to female ratio among occupants hospitalized for serious injury as a result of a motor vehicle collision was 1:7 to 1. However, the ratio of males to females in the ejected group was 3.2 to 1 (Gongora, 2001).

When studied in relation to spinal cord injury, ejections from the vehicle during a collision are common and implicated as important determinants of serious and fatal injury.

Collision Type

Using data from the National Crash Severity Study, Huelke (1981) examined crash type and its relationship to the occurrence of severe neck and spine injury. These investigators found that while front impact collisions were the most common type of collision, the rate of severe cervical injury among occupants was highest in rollover collisions. While rollover collisions accounted for only 3% of all collisions (n=1863) rollovers were associated with almost 40% of severe neck injuries (91 of 251 injuries). In Wiggelsworth's (1992) study of 67 spinal cord injury cases arising from motor vehicle collisions, the author states that the most important finding was the importance of vehicle rollovers in the causation of spinal cord injury. Wigglesworth found that 86% of the crashes that resulted in spinal cord injury were rollover collisions. This study also found that 77% of the rollover crashes that resulted in spinal cord injury occurred on a rural roadway.

Of the motor vehicle crashes that resulted in spinal cord injury reported to the Australian Spinal Cord Injury Register, 42% were rollover crashes (O'Connor, 2002). O'Connor also noted that when cases of occupant spinal cord injury were compared to other seriously injured (non-spinal cord injured) occupants, the likelihood of spinal cord injury was five times higher for occupants in cars involved in single vehicle rollovers versus not (O'Connor, 2002). Furthermore, when type of vehicle was accounted for, the likelihood of spinal cord injury was ten times higher in non-sedan type cars than in sedan

type cars. Treacy (2002) studied factors associated with the occurrence of single vehicle rollovers and found that excessive speed, rural roadways and gender were all significantly associated with this type of collision. The author used data from several sources including a trauma center trauma database, coroner's reports and police reports and found that single vehicle rollovers' accounted for 30% of all collisions and 29% of all injuries and deaths (Treacy, 2002).

In the studies that examined collision type in relation to spinal cord injury, rollover collisions are strongly associated with occurrence of spinal cord injuries among vehicle occupants.

Age

Although people of every age are vulnerable to spinal cord injury in a car crash, the majority of victims are young adults (Huelke, 1981; Hadley, 1986; Wigglesworth, 1992; Sasso, 1997). According to these studies, the mean age of people with spinal cord injury as a result of motor vehicle collisions ranges from 28 to 35 years. O'Connor reported that 85% of motor vehicle collision related cases of spinal cord injury are aged 15 to 44 years (O'Connor, 2002). Heulke (1981) found that car crash occupants aged 16 to 25 years have double the rate of serious cervical injury compared to every other age group. This investigator concludes that the increased rate of spinal cord injury in young people was related to their over involvement in serious, high speed collisions rather than an anatomical vulnerability to spinal cord injury. In Tavris's study of drivers for drivers hospitalized after motor vehicle crashes, the injury rate for loss of control crashes peaks in the 15 to 24 age group (Tavris, 2001).

Tolonen and colleagues examined fatality reports from motor vehicle collisions involving private cars and vans in Finland during 1972-1982, in which an injury to the cervical spine was the main cause of death (n=289). The authors conclude that risk of sustaining a cervical spine injury that is fatal increases with increasing age; patients aged 16 to 25 years had the lowest risk and patients aged over 60 years had the highest risk of sustaining a fatal cervical spinal injury (Tolonen, 1986).

While all the studies found that spinal cord injuries occur most often among young adults, both old and young ages are implicated in the literature as risk factors for spinal cord injury during a motor vehicle collision. Young people seem to be at risk of spinal cord injury due to crash characteristics and older persons are at risk possibly due to anatomic vulnerability.

Gender

Invariably, in the studies identified for this literature review, spinal cord injury as a result of car crashes is much more common among males than females. The male to female ratio in these studies ranged from 1.4 to 2.6:1. The study by Sasso and colleagues found a relationship between gender and severity of spinal cord injury resulting from a car crash. They report that 54% of females had neurologically intact lesions versus only 40% of males. Sasso calculated that the odds of surviving a car crash with an intact lesion were greater for females than for males (odds = 0.63, $p < 0.001$; Sasso, 1997).

Laapoti and colleagues examined the original team reports of the Road Accident Investigation Teams for all fatal car crashes among young drivers aged 18 to 21 years in Finland during 1978-1991 (n=413; Laapotti, 1998). This study found that male drivers involved in loss of control collisions were often speeding and were under the influence of

alcohol more often in loss-of-control collisions than in other types of crashes. In addition, they also note a gender difference in crash factors. Specifically, male drivers' loss of control collisions took place during evenings and nights while female drivers' loss-of-control collisions usually occurred with slippery road conditions. The authors concluded that compared to females involved in loss of control crashes, high risk driving behaviors such as speeding and drinking alcohol, among young male drivers played a larger role in loss-of-control crashes. For example, these investigators noted that for loss of control collisions, 83% of male drivers were speeding at the time of the crash versus only 40% of females (Laapotti, 1998). The authors also reported that, on average, in fatal loss of control collisions, male drivers exceeded the posted speed limit by 24.3 km/hr versus 12.9 km/Hr for female drivers (Laapotti, 1998).

Literature Review Summary

The existing literature provides insights into factors associated with motor vehicle collisions that result in spinal cord injuries. Namely, being male, not wearing a seatbelt, speeding, being involved in a rollover collision and being ejected from the vehicle are factors associated with the occurrence of spinal cord injuries in serious crashes. However, most studies had small numbers of subjects and did not explore the associations between these factors in a quantitative manner.

Authors of previous studies that examined motor vehicle related spinal cord injury did not examine drivers separate from passengers. It is important from an injury prevention standpoint, to elucidate factors for drivers. The driver of the vehicle played an active role in the crash versus the passive role of the passenger. Injury prevention

strategies have a different focus for drivers versus passengers due to the culpability of the driver.

Furthermore, the existing studies do not provide measures of association for the risk factors nor are there any estimates of risk that control for the effects of other factors simultaneously. In particular, the combined effects of gender, vehicle type (pickup trucks) in rural settings on the occurrence of crashes that result in spinal cord injury among drivers have not been estimated. Thus, the impetus for this study was to estimate the degree of association between these factors and the occurrence of spinal cord injury among drivers.

Table 1. Summary Findings from Studies of Motor Vehicle Related Spinal Cord Injury

Author, study sample	Age, Sex	Seat-belt use	Crash type	Ejections	Roadway and vehicle type
Huelke, 1981 Occupants of tow-away passenger car crashes n=10,151	more serious cervical injuries in ages 16-25 sex: not reported	83.6% did not wear seatbelt	cervical injury rate higher for rollovers	33% were ejected. ejected occupants 36 times more likely to have fatal cervical injury	Not reported
Hadley, 1985 Hospitalized patients with spinal cord injury due to car crashes in Arizona n=73	median age 35 years 59% male	3% use rate 58% unknown use 39% did not wear seatbelt	50% of crashes were single vehicle	53% were ejected	Not reported
Cushman, 1991 Drivers hospitalized with spinal cord injury n=30	Mean age 33.7 years. 72% male	Drivers with spinal cord injury wore seatbelts less often than controls (0% vs. 26%)	Rollovers equal in the two groups (not a factor)	Not reported	Not reported
Wigglesworth, 1992 Hospitalized patients with spinal cord injury due to car crashes in Australia n=67	Mean age 33.7 years 72% male	44% wore seatbelts	86% were rollovers	Not reported	77% of crashes occurred on rural roads. Vehicle not reported

Table 1 (continued). Summary Findings from Studies of Motor Vehicle Related Spinal Cord Injury

Author, study sample	Age, Sex	Seat-belt use	Crash type	Ejections	Roadway and vehicle type
Thurman, 1995 Hospitalized with spinal cord injury due to car crashes in 1989-91 in Utah n=110	Young males were at highest risk of injury 76% male	25% used seatbelts	70% were rollovers	39% were ejected	Not reported
Sasso, 1998 Hospitalized with spinal cord injury due to motor vehicle collisions in Illinois 1971-1993 n=1352	Median age 28 yrs 67% male. 54% of females vs. 40% of males had intact injury	14% used seatbelt, 86% did not and 10% unknown. 61% of belted and 42% of unbelted had intact lesions	Not reported	Not reported	Not reported
O'Connor, 2002 Hospitalized with spinal cord injury due to motor vehicle collisions in Australia over a five year period n=82	86% were 15-44 years	60% were not wearing a seatbelt	37% of spinal cord injuries were rollovers. Spinal cord injury was ten times more likely in non-sedan cars in a rollover.	Not reported	Roadway not reported. Likelihood of spinal cord injury was five times higher for occupants of non-sedan type cars

Chapter 3. Methodology

Study Design

This study is a cross sectional study of patients seriously injured in car crashes and included in the provincial trauma registry. This study used a dataset provided by the Alberta Trauma Registry, and is a retrospective review of cases included in that dataset.

Study Subjects

The source population includes all people aged 16 and older who were driving a passenger vehicle and were seriously injured in a motor vehicle collision and treated at a hospital that participates in the Alberta trauma registry between April 01, 1995 and March 31, 2001. Drivers could either be residents or non-residents of Alberta injured and treated in Alberta or residents or non-residents of Alberta injured outside Alberta and transferred to a hospital that contributes data to the trauma registry. As such the study group consists of drivers injured in motor vehicle collisions in Alberta, British Columbia, Saskatchewan, Northwest Territories, Yukon and the Northwest United States (Montana, Idaho and Washington), although most were Alberta residents. The hospitals that contribute data to the trauma registry are the Foothills Medical Center (Calgary), Alberta Children's Hospital (Calgary), Royal Alexandra Hospital (Edmonton) and the University of Alberta Hospital (Edmonton). Injured patients admitted to one of these hospitals who had an injury severity score of 12 or more are included in the registry.

Inclusion Criteria

The current study includes trauma patients who were included in the trauma registry and who met the following inclusion criteria: admitted to the Foothills Medical Center (Calgary), Alberta Children's Hospital (Calgary), Royal Alexandra Hospital

(Edmonton) or the University of Alberta hospital (Edmonton) between April 01, 1995 and March 31, 2001; injury severity score of 12 or more; aged 16 or older, injured in a motor vehicle traffic collision (ICD-9 External Cause of Injury Codes 810-819.9); and injured while driving a passenger vehicle (car, van, mini-van, sport utility vehicle, or pick-up truck).

Exclusion Criteria

No one meeting the inclusion criteria was excluded from this study.

Case Definitions

Patients with spinal cord injury were identified using the "Uniform Data Systems Case Definition for Spinal Cord Injury" set out by the Center For Disease Control and Prevention (Center For Disease Control and Prevention, 1987). According to this definition, spinal cord injury is defined as acute traumatic lesions of the neural elements of the spinal column resulting in any degree of transient or permanent sensory, motor or neuropathic deficit (ICD-9-CM codes 806.00 - 806.9 and 952.0-952.9).

Extent of neurologic injury as either complete or incomplete for spinal cord injury was defined using the ICD-9- CM according to the neurosurgical diagnosis provided in the patient discharge summary. The following ICD-9-CM codes indicate complete spinal cord injuries: 952.01, 952.06, 952.11,952.16, 806.01, 806.06, 806.11, 806.16, 806.21, 806.26, 806.31 and 806.36. The following ICD-9-CM codes represent incomplete spinal cord injuries: 952.02-05, 952.07-09, 952.12-15,952.17-19,806.02-05, 806.07-09, 806.1, 806.12-15, 806.17-19, 806.22-25, 806.27-29, 806.3,806.32-35, 806.37, 806.38 and 806.39 (Health Care Financing Administration, 1989).

Identification of head injuries was done using the following IDC-9 codes: 803.00 to 804.9 and 850.00 to 854.99. Severe head injuries were defined as a head injury with an associated abbreviated injury score of four or greater (Association for the Advancement of Automotive Medicine, 1990).

Trauma Registry Data

In accordance with the trauma registry data system protocol established by the Canadian National Trauma Registry, in April of 1995, Alberta began to collect data on all major trauma patients hospitalized at a designated trauma center in the province. Alberta uses the same data dictionary to collect standardized trauma data on a defined group of patients using a commercial software program by trained injury data coders. The trauma registry data dictionary is a list of all the fields of information, their definitions and how they are to be collected. The data dictionary used in Alberta was copied and adapted from Ontario's data dictionary. Using this data dictionary, hospital based trauma data analysts abstract and code information from the patient care record and enter it into a database. The information collected by the trauma registry includes facts related to the injury event, patient demographics, the types and severity of injuries sustained in the event, the process of care (pre-hospital through discharge), and patient outcomes.

Data collected by the trauma registry regarding the injury event includes date, time, and place of injury, protective devices in use, location of injury, whether or not there was a fatality at scene, mechanism of injury encoded as an E-code, cause of injury (detailed text description) whether or not the injury was work related, type of vehicle, type of collision, collision detail, position in vehicle, distance ejected, extrication time,

ambulance response time, number of emergency personnel at scene and where the patient was sent to from the scene.

The Alberta trauma registry collects data on seriously injured patients (injury severity score 12 or greater) who (a) sustain traumatic injuries that require treatment at a trauma center and are then admitted to a trauma center; (b) are transferred to a trauma center; or (c) are dead-on-arrival or die in the emergency department. The Alberta trauma registry does not collect data on the following types of patients: patients admitted to a hospital that is not designated as part of the Alberta Trauma Registry; those who die at the scene of the traumatic injury and patients treated in the emergency department of a designated trauma center and discharged home.

Identification of patients who meet the criteria for inclusion in the trauma registry is done in a systemic manner on a daily basis at each of the four participating institutions. To ensure all appropriate patients are included in the registry, all injury admissions, discharges and Emergency Department resuscitations are reviewed. In a typical year, over 6000 injury admissions are reviewed at the four sites to determine eligibility for the trauma registry. Patients are eligible for inclusion in the trauma registry if their Injury Severity Score is 12 or greater. Based on admission diagnosis, patients with injuries are flagged and reviewed by the data analyst. Using injury diagnosis information from the admission summary, CT scan, X-rays and operative reports, a list of their injuries is compiled and an initial Injury Severity Score is calculated for each patient.

The Injury Severity Score is an index of anatomic injury severity (Baker et al, 1974; Baker and O'Neill, 1976). The Injury Severity Score is derived from the Abbreviated Injury Score. The Abbreviated Injury Score is a numerical scale that assigns

a score from one (minor injury) to six (virtually unsurvivable injury) to each of six body regions: head and neck, face, chest, abdomen and pelvic contents, extremities and pelvic girdle and external (cuts and contusions). Scores are objective assessments of severity assigned to specific anatomical diagnoses based on four criteria: threat to life, permanent impairment, treatment period and energy dissipation. For each of six body regions, the AIS is used to classify any traumatic injury in a body region based on anatomic lesion under five different groups: whole area, vessels, nerves, internal organs and skeletal. The Injury Severity Score is the sum of squares of the highest Abbreviated Injury Scores in each of the three most severely injured body regions. The Injury Severity score has been widely used to assess the combined effects of multiple injuries (Boyd, 1987; Mackenzie, 1986).

The software used for the trauma registry is Collector®, a complete data management and report writing package. The Collector® trauma registry system includes a program called Tri-Code® that is used by the data analysts to automatically calculate the injury severity scores. A field test of the accuracy of Tri-Code® showed that it correctly applied the Abbreviated Injury Score severity codes in 98.3% of cases (Long, 1994). The correctness of the resulting Injury Severity Scores arising from Tri-Code is dependent on complete injury diagnosis by trauma physicians and well documented injury descriptions in the patient medical record coupled with proper data entry of the injuries. The data analysts who do the data entry receive annual training workshops in the use of the Abbreviated Injury Scores scoring manual. The Collector system was developed by an American company and is supported by Digital Innovation, Inc. based in Maryland. This application is used by over 300 hospitals worldwide including Canada,

United States, Australia, New Zealand and Sweden (Owen, 1999). It has been in use at all of the institutions that participate in the Alberta trauma registry since April 1995.

Once registry eligibility has been determined, data is abstracted from the patient record into the trauma registry. Effort is made to gather as much information as possible. In some cases, follow-up is necessary with pre-hospital care providers, rural hospitals, sending hospitals, as well as Alberta Health and Wellness. Depending on the field, trauma registry data is generally complete. For example, in the dataset used in this study, of the 20 fields of information per patient obtained from the trauma registry, only six fields had missing data. The fields and numbers of cases with missing data were as follows: 176 cases missing from seatbelt use, 18 missing from ejected from vehicle, 8 missing from address, 17 missing from rural or urban roadway and 9 cases missing from type of collision. In all, 1577 of 1735 (90.8%) patients had all fields completely filled in and 176 had at least one item of information missing. In these instances, the data field was left blank so it is not known whether the information was available and not filled in or whether or not it was simply not known. The correctness and validity of the data in the Alberta trauma registry has not been formally determined.

It is important to note that the Alberta Trauma Registry does not contain all fatal and non-fatal injury occurrences within the province. However, I performed an informal assessment of the completeness of the dataset with respect to patients hospitalized for traumatic spinal cord injury in 2001. By cross-referencing patients hospitalized for spinal cord injury according to the data maintained by the provincial health department with trauma registry cases, I found that the trauma registry correctly identified all the cases of spinal cord injury who were hospitalized during the period April 01 1995 to March 31,

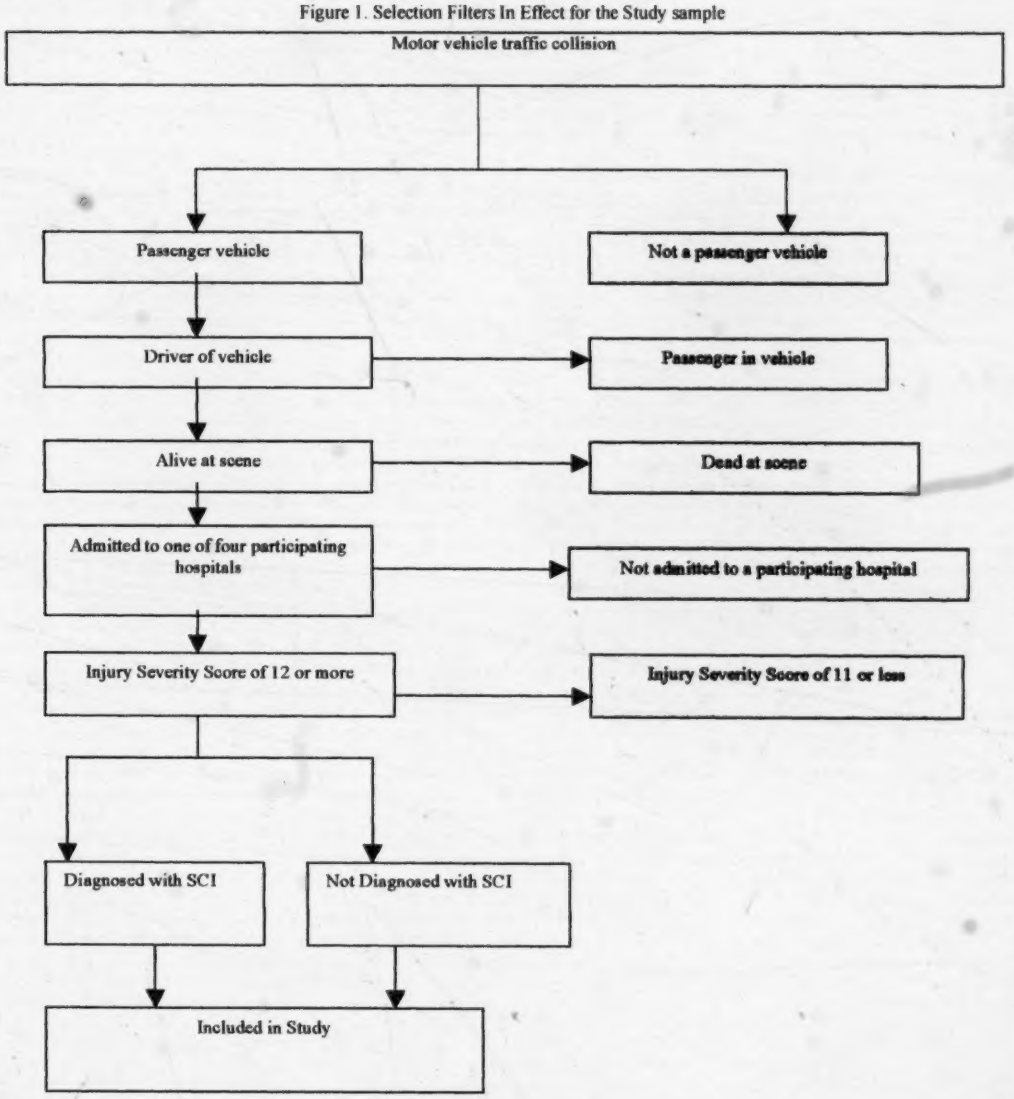
2001. Thus, it is a comprehensive source of data for patients hospitalized with spinal cord injuries in Alberta. Three hospitals treat spinal cord injuries and all three of these sites participate in the trauma registry.

The number of licensed drivers in Alberta by age and year was obtained from the Transportation Safety Services Division of Alberta Transportation. This information was used as the denominator for the incidence rate calculations provided in Table 3.

Selection filters

The trauma registry is not a comprehensive data set that captures information regarding all people injured in car crashes. It contains information only about the most seriously injured patients who survived long enough post injury to be admitted to one of four participating hospitals. Figure 1 depicts the selection filters in effect for the study sample.

Figure 1. Selection Filters In Effect for the Study sample


Motor vehicle traffic collision
Passenger vehicle
Not a passenger vehicle
Driver of vehicle
Passenger in vehicle
Alive at scene
Dead at scene
Admitted to one of four participating hospitals
Not admitted to a participating hospital
Injury Severity Score of 12 or more
Injury Severity Score of 11 or less
Diagnosed with SCI
Not Diagnosed with SCI
Included in Study

Explanatory Factors

Potential explanatory factors explored in this study include the following information: demographics (age, gender, urban or rural residence), place of injury, time and date and day of injury, injury diagnosis (ICD9 N code), injury severity (abbreviated injury score and injury severity score) type of vehicle, type of collision, primary impact locations, primary E-code, protective devices in use, distance ejected from vehicle, length of stay, discharge disposition and status.

Data Preparation

The study database was analyzed with SPSS Version 11. The database was prepared by first importing it into SPSS and then checking each field for missing or erroneous values.

Mean and standard deviation were calculated for continuous variables. Frequency counts and proportions were done for dichotomous variables. The sample is described using frequencies, proportions, means and standard deviations (Table 2). Differences in proportions were compared using Chi square tests.

A multivariable logistic regression modeling strategy was used to determine factors associated with spinal cord injury among drivers. The purpose of this type of analysis was to estimate the degree of association between the occurrence of spinal cord injury and potential explanatory factors (age, gender, vehicle type, collision type, type of roadway and whether or not the driver resides in a rural or urban locale). The dependent variable was whether or not a driver had a spinal cord injury as a result of a serious but survivable motor vehicle collision. Drivers who were involved in a motor vehicle collision that resulted in major trauma and spinal cord injury were compared to drivers

who suffered major trauma but did not have a spinal cord injury. Seriously injured drivers were assigned a value of 1 if they had a spinal cord injury and a zero if they did not.

It is important to note that the purpose of this study was to study the associations between the independent variables and the dependent variable (whether or not a driver had a spinal cord injury) as opposed to building a causal model for the occurrence of spinal cord injury among drivers.

Thus, the objective is to obtain an epidemiologic measure of association (odds ratios) for each independent variable included in this study. Odds ratios were calculated using logistic regression. Hosmer and Lemshow state the general form of the logistic regression model (Hosmer and Lemshow, 1989) as:

$$\text{LOGIT}(Y/X) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots + \beta_P X_p$$

The odds ratio is calculated by taking the log of the beta value estimated from the logistic regression equation as stated above.

The independent variables that were tested were: age (as a continuous variable and as a dichotomous variable; under age 20 = 1, 20 and older = 0), gender, restraint use, whether the driver was ejected from vehicle, type of crash, single or multiple vehicle collision, type of vehicle, type of roadway (rural or urban) and place of residence (rural or urban). Age was initially entered as a continuous variable as this lends the most precision to the estimate. It was then dichotomized for the purpose of interpretation, into under and older than age 20 years in accordance with findings from the literature review that suggest that young drivers (aged 20 and less) are more prone to serious crashes that result in spinal cord injury.

Univariate logistic regression was used to calculate crude odds ratios and associated 95% confidence ratios for each independent variable. Multivariable modeling was used to calculate adjusted odds ratios. All biologically important variables and the variables that were associated with the dependent variable at $p < 0.10$ in the univariate models were included in the multivariable models.

Where the explanatory variables were highly related statistically and conceptually, and therefore likely to create problems with collinearity, I selected the variable to be included in the model according to its biologic importance and its contribution to the fit of the model.

Assessing Interactions

Interactions between variables were tested for using the following equation:

$$\text{LOGIT}(Y/X) = \alpha + \beta_1 A + \beta_2 B + \beta^3 A \times B.$$

The null hypothesis that was tested was; "there is no interaction between the two variables", (the coefficient on $\beta 3$ is zero). If the Wald statistic for $\beta 3$ is associated with a p value of greater than 0.05, it is concluded that there is no significant multiplicative interaction between the two variables being tested.

A stratified analysis was used to assess factors associated with spinal cord injuries among drivers who were thrown from the vehicle versus those who remained inside the vehicle at the time of the crash. The data was stratified according to ejection status (ejected versus not) and crude odds ratios for each variable were calculated and compared.

Ideally, another level of stratified analysis would have occurred, namely, for drivers who were not ejected from the vehicle, the data would have been further stratified

into belted and non-seat belted drivers. However, the data was too sparse to permit a meaningful analysis of these strata.

According to Peduzzi et al, for studies that use regression modeling, at least ten events per explanatory factor are needed (Peduzzi, 1995). Given this, in order to estimate the degree of association between occurrences of spinal cord injury among non-ejected drivers who were not wearing a seatbelt, and type of vehicle, type of roadway, place of residence and collision type, at least 50 drivers in the spinal cord injury group were needed.

Ethics

The Health Research Ethics Board of the University of Alberta approved the study (Appendix I). Permission to use trauma registry data was granted by the Director of the Alberta Trauma Registry. The dataset supplied for this study is completely de-identified. Specific information regarding names, addresses, phone numbers, health information numbers and treating institutions were removed from the data prior to creating the dataset used in this study.

Chapter 4. Results

Between April 01, 1995 and March 31, 2001, 1753 drivers of passenger vehicles involved in a motor vehicle collision were identified from the trauma centers that report to the trauma registry. In this six-year period, there were 476 people with spinal cord injury and 56% (n=266) of these were injured during a motor vehicle crash. Of these patients, almost half (n=117, 44%) were driving the vehicle at the time of injury. On average each year for the past six years, there were 290 drivers injured in passenger vehicle collisions that were reported to the provincial trauma registry. Of these seriously injured drivers, on average each year 20 of them suffered spinal cord injury.

The rate of hospitalization for spinal cord injury among drivers who were residents of Alberta ranged from 0.6 cases/100,000 licensed drivers to 1.0 cases/100,000 licensed drivers (Table 2). The rate of motor vehicle related hospitalization for spinal cord injury among male drivers males is double that seen among female drivers. For males the rate of hospitalization for spinal cord injury as a result of a serious MVC ranged from a high of 1.4 cases per 100,000 licensed male drivers in 1996/97 and 1997/98 to a low of 0.9 cases/100,000 licensed male drivers in 1995/96. For females the rate ranged from a high 0.6 cases per 100,000 licensed female drivers in 1997/98 to a low of 0.3 cases/100,000 licensed female drivers in 1995/96 and 2000/01.

Table 2. Alberta 1995-2001: Hospitalization For Spinal Cord Injury Among Drivers Of Passenger Vehicles Injured During A Motor Vehicle Collision-Total Number By Gender And Hospitalization Rate Among Residents Of Alberta

	95/96	96/97	97/98	98/99	99/00	00/01
Number of hospitalizations for spinal cord injury	17	22	22	20	20	16
Male	14	18	15	15	15	13
Female	3	4	7	5	5	3
Albertans						
Number of hospitalizations for spinal cord injury	15	19	21	19	19	14
Male	12	15	15	14	14	11
Female	3	4	6	5	5	3
Rate of hospitalizations for spinal cord injury per 100,000 licensed drivers	0.8	0.9	1.0	0.9	0.9	0.6
Male	1.1	1.4	1.4	1.2	1.2	0.9
Female	0.3	0.4	0.6	0.5	0.5	0.3

Table 3 lists the characteristics of the 1753 drivers who were injured in a serious passenger vehicle crash and who were admitted to a participating trauma center with and without spinal cord injury.

Table 3. Characteristics Of Drivers Of Passenger Vehicles Who Were Seriously Injured And Hospitalized After A Motor Vehicle Collision

Factor	Seriously Injured Drivers with Spinal Cord Injury (n=117) n (%)	Seriously Injured Drivers without Spinal Cord Injury (n=1636) n (%)	All Seriously Injured Drivers (n=1753)
Age: mean (SD)*	37.3 (18.1)	39.4(17.3)	38.2 (17.2)
Under age 20	16 (13.6)	225 (13.8)	241 (13.7)
Males	90 (76.9)	1166 (71.2)	1256 (71.6)
Vehicle Type			
Pick-up Truck	44 (37.6)	398 (24.3)	442 (25.2)
Car/Van/SUV	73 (62.3)	1238 (75.6)	1311 (74.7)
Seat Belt Use			
Belted	44 (37.6)	785 (47.9)	829 (47.2)
Unbelted**	69 (58.9)	679 (41.5)	748 (42.6)
Ejected from Vehicle**	34(29.0)	311 (19.1)	345 (19.6)
Pre-Injury Alcohol Use			
Tested for Alcohol Use	37 (31.6)	582 (35.5)	606 (34.5)
Not tested	80 (68.3)	1054 (64.4)	1147 (65)
Address			
Rural	93 (79.5)	954 (58.3)	1047 (59.7)
Urban**	24 (20.5)	682 (41.6)	706 (40.3)
Type of Roadway			
Rural	107 (91.4)	1166 (71.3)	1273 (72.6)
Urban **	10 (8.5)	470 (28.7)	480 (27.4)
Type of Collision			
Rollover**	86 (73.5)	488 (29.8)	569 (32.4)
Single Vehicle collisions	92 (78.6)	614 (37.5)	706 (40.2)
Single Vehicle rollovers	85 (72.6)	471 (28.7)	556 (31.7)
Injury Severity Score Mean (SD)	28.4 (12.6)	25.5 (11.7)	25.4 (11.5)
Head Injuries			
Any	39(33.3)	1034 (63.2)	1073 (61.2)
Severe	29(24.7)	516 (31.5)	545 (31.1)
Days in hospital Mean (SD)	29.5 (27.1)	16 .7(20.6)	17.1 (20.3)

* SD: standard deviation ** Some missing data. 13 cases missing from seatbelt use, 18 cases missing from ejected from vehicle, 8 cases missing from address, 17 cases missing from rural or urban roadway and 9 cases missing from rollover)

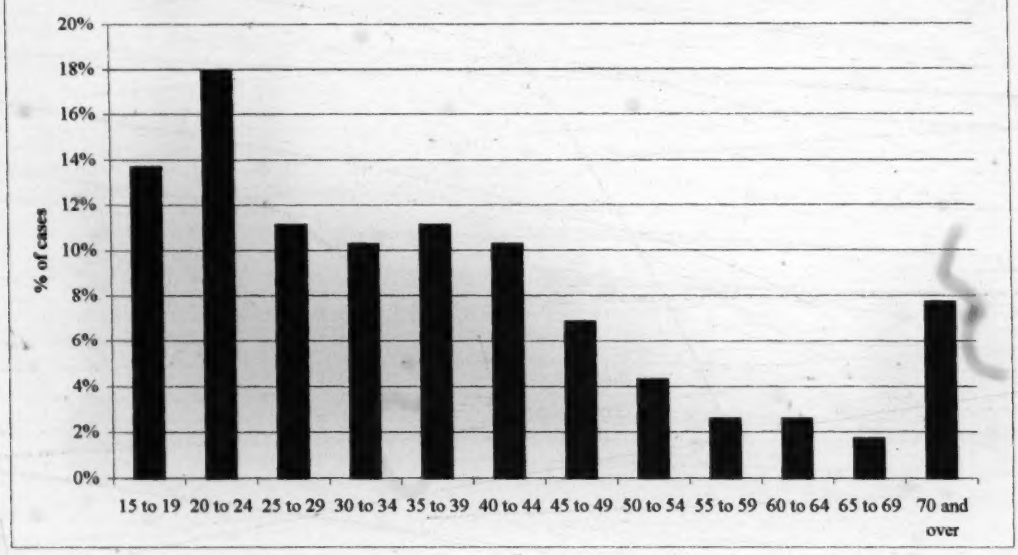
Gender

The majority of spinal cord injury among drivers who were hospitalized after a motor vehicle collision occurred among males (77%) compared to females (23%). Overall, the three to one male to female ratio varied little over the six years; male drivers consistently outnumbered female drivers each year throughout the six-year study period.

Age

Spinal cord injury as a result of motor vehicle collisions among drivers primarily affects young adults; fifty drivers (43%) with spinal cord injury were less than 30 years of age and 16 (14%) were less than 20 years of age. The average age of drivers with spinal cord injury was 37.3 years (range 16.2 to 83.4 years). Persons older than 60 years comprised 12% of the drivers with spinal cord injury. There were disportionately more female teen drivers than males ($\chi 2=4.24$, d.f. =1, $p=0.035$). Females aged 16 to 19 comprised 26% of all injured females while males aged 16 to 19 years made up only 10% of all injured males. There was an eight-year difference in mean age at time of injury for females versus males (mean age 30.1 (S.D. 16.7) vs. 38.4 (S.D. 18.7) years, $p=0.007$). Figure 2 depicts the number of drivers hospitalized with spinal cord injury by age group in five-year groupings.

Figure 2. Seriously Injured Drivers Who Sustained a Spinal Cord Injury: Distribution by Age at Injury

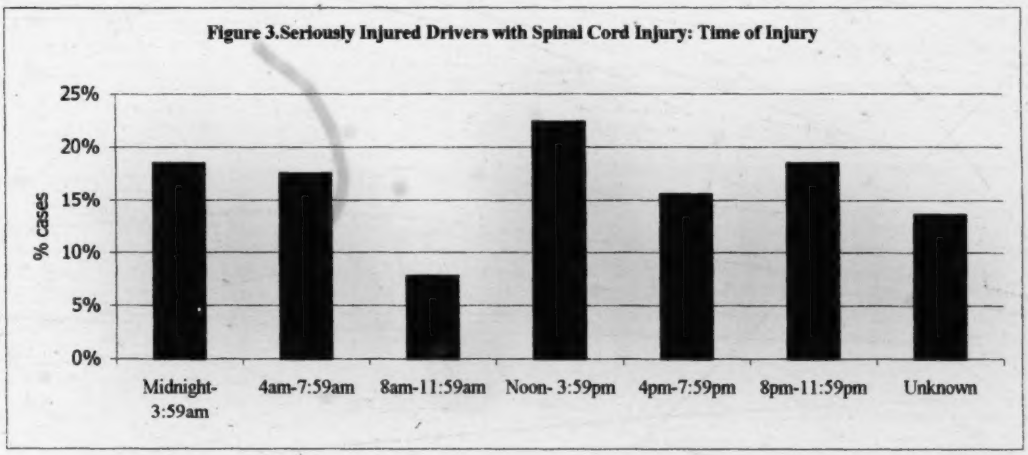


Place of residence & place of injury

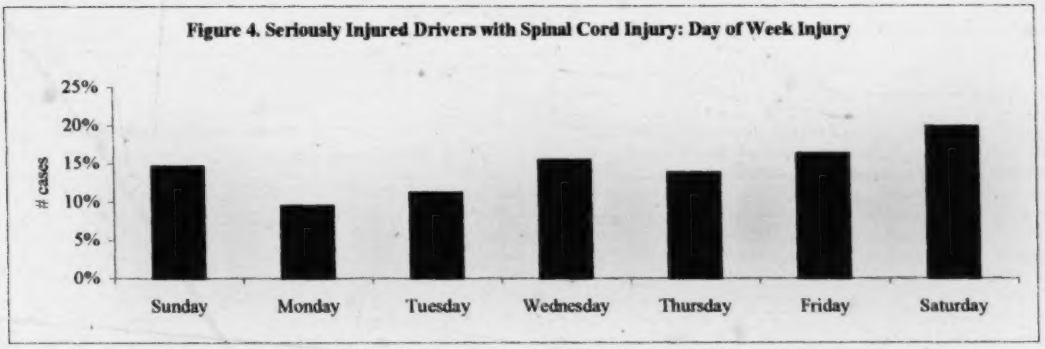
Of the 117 drivers with spinal cord injury who were admitted and treated at one of the trauma centers that participate in the provincial trauma registry, 107 (91%) were residents of Alberta and 10 (9%) were from out of province. The vast majority of drivers with spinal cord injury reside in rural areas. Of the 117 drivers with spinal cord injury, 77% were documented as living in a rural area. Only 23% were listed as residents of an urban area. For rural residents, only one driver was injured on an urban roadway. Almost all the rural dwelling drivers were injured on a rural roadway (99%). For urban dwellers, 38% were involved in car crashes inside an urban area and 63% of urban dwelling drivers were inured on a rural roadway. In all, 91% of drivers with spinal cord injury were injured on a rural roadway.

Time, day and month of injury

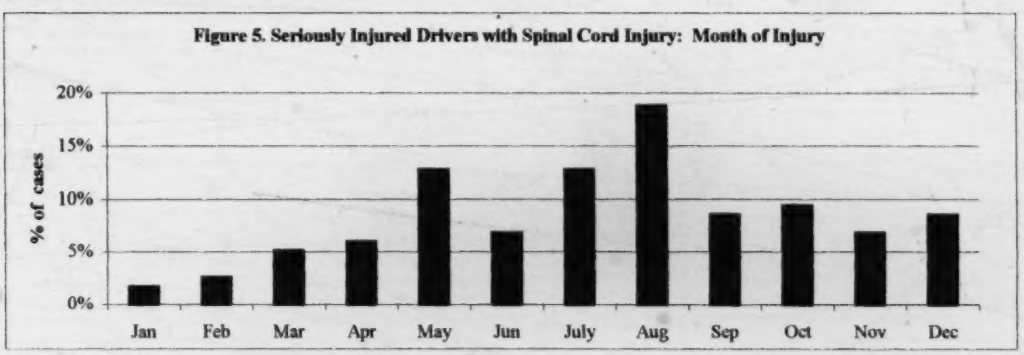
Although the number of crashes were fairly evenly distributed throughout the day and night, the most common time for car crashes that resulted in spinal cord injury among drivers was between the hours of noon and 4 pm. Almost a quarter of the crashes occurred during this four hour interval (n=23, 22%). Crashes resulting in spinal cord injury occurred less frequently in the early morning hours of 8 am 12 pm. Figure 3 shows the distribution of spinal cord injuries by time of day. There was no significant difference in the distribution of crashes across the four hour time of day intervals ((χ2=7.47, d.f.=5, p=0.187).



By day of week, most crashes occurred on a Saturday (20%) and the least number of crashes occurred on a Monday (9%). Figure 4 shows the distribution of injuries by day of week of injury. There was no significant difference in the distribution of crashes across the days of the week (χ2=5.52, d.f.=6, p=0.146).



There was statistically significant variation in the number of car crashes by month of the year ($\chi 2$=34.72, d.f. = 11, p=0.0002). The most spinal cord injury car crashes occurred in the month of August (19%) followed by May (13%) and July (13%). The least number of crashes occurred during January (2%) and February (3%). The month-by-month variation results in significant seasonal variation in frequency of crashes ($\chi 2$=15.47, d.f.=3, p=0.001). Almost 40% of all crashes occur in summer (38%), followed by fall (25%) spring (24%) and winter (13%). Figure 5 depicts the number of drivers with spinal cord injury by month of injury.



Alcohol use

Only 37 of the 117 drivers (32%) had a blood alcohol test after the motor vehicle collision that resulted in spinal cord injury. The remaining 68% of drivers were not tested for pre-injury alcohol use.

Of the 37 drivers who were tested, 28 (76%) drivers had consumed alcohol (tested positive) prior to their car crash. Upon admission to a trauma center, the average blood alcohol concentration of the 28 drivers who tested positive was 35.0 mmol/L (range 2.8 - 82.7 mmol/L, S.D. = 18). The legal limit is 17 mmol/L.

An equal proportion of males and females were tested for pre-injury alcohol use upon admission to a trauma center; 9 female (33%) and 28 (31%) male drivers were tested. However, the odds of a male driver testing positive for pre-injury alcohol use were increased by a factor of 3 when male drivers are compared to females (crude OR 3.13, 95% CI 0.75-14.58). Proportionately more males than females tested positive for pre-injury alcohol use (44% vs. 71%, p=0.15). While the average time from injury to testing for blood alcohol was five hours, for the male drivers who were tested, 17 (61%) were still legally drunk (BAC >17 mmol/L) upon admission to a trauma center. Among women who were tested, two (22%) had a BAC of 17 mmol/L or greater.

Seatbelts

Only 44 (38%) of drivers with spinal cord injury were documented as wearing a seatbelt at the time of injury. The majority of drivers were recorded as not wearing a seatbelt (59%) and seatbelt use was not known for the remaining 3% of drivers. On average, drivers who were wearing a seatbelt were 6 years older (mean age 40.4 years vs. 34.1 years, p=0.042) than drivers who were unbelted. There was also a difference in

seatbelt use between genders. Women were more likely to have been wearing a seatbelt at the time of injury (crude OR 1.80, 95%CI 0.71-4.21). Thirteen women (48%) and 31 men (34%) were wearing a seatbelt the time of injury.

Among the 44 drivers who used seatbelts, only one driver (2%) was ejected from the vehicle during the crash. A very different result is seen for drivers who were not wearing a seatbelt. Almost half of the drivers who not wearing a seatbelt were ejected from their vehicle during the crash (n=33, 48%). The odds of being ejected during a crash were increased by a factor of 39 when belted drivers are compared to non-belted drivers (crude OR 39.41, 95% CI 9.72 –160.64).

A greater percentage of rural drivers were documented as not wearing a seatbelt than urban drivers; 62% of rural dwellers were not wearing a seatbelt compared to 46% of urban dwelling drivers (crude OR 1.95, 95% CI 0.89 – 4.96).

Type of crash

Using the primary ICD 9-E-code, 91 crashes (78%) were coded as "single vehicle collisions' in which no other vehicle is involved in the crash. The 91 single-vehicle collisions include the following types of crashes: rollover, loss of control, no collision (93%), rollover, impact with fixed object (4%), impact with fixed object then rollover (3%).

There were 26 crashes (22%) that were assigned a primary e-code indicating a traffic collision that involved at least one other motor vehicle. These 26 multi-vehicle collisions, included the following types of crashes: right angle (28%), rear-end (24%), off-road right (24%), head-on (23%) and side-swipe-opposite direction (1%).

Vehicle type

There were 44 pick-up trucks (38%) and 73 (62%) passenger vehicles (cars, mini-vans, sport-utility vehicles). Drivers of pick-trucks were younger (mean age 33.3 vs.38.4 years, p=0.052) than drivers of passenger vehicles. Eighty four percent of the pick-up truck drivers were male and 16% were female. Seventy three percent of the drivers of passenger vehicles were male (n=53) and 27% (n=20) were female. Among pick-up truck drivers, 89% of the collisions were single vehicle rollover collisions which were coded as 'driver lost control". Pick-up truck drivers were much more likely to be involved in a single vehicle rollover collision compared to drivers of passenger vehicles, (crude OR 7.21, 95% CI 2.86 – 18.84).

Types of injuries

Spinal cord injuries occur with or without injury to the spine. Injuries characterized by fractures of the vertebral column with spinal cord lesion comprised 83% (n=97) of the injuries while trauma to the spinal cord without evidence of spinal bone injury occurred in 17% of drivers (n=20). According to the ICD9 CM system of classifying spinal cord injury, 40% (n=43) of the drivers had complete spinal cord injury and 60% (n=70) had incomplete lesions. Table 4 lists the types of spinal cord injuries that were diagnosed among the 117 drivers by ICD-9 Code.

Table 4. Numbers of Types of Spinal Cord Injuries by ICD9 Code

ICD-9 CM Code	Description	Number of Drivers
Fractures Of The Vertebral Column With Spinal Cord Lesion		
806.01	C1 -C4 level with complete lesion of cord	2
806.03	C1 -C4 level with central cord syndrome	4
806.04	C1 -C4 level with other specified spinal cord injury	6
806.05	C5 -C7 level with unspecified spinal cord injury	4
806.06	C5 -C7 level with complete lesion of cord	25
806.07	C5 -C7 level with anterior cord syndrome	2
806.08	C5 -C7 level with central cord syndrome	7
806.09	C5 -C7 level with other specified spinal cord injury	21
806.2	T1 -T6 level with unspecified spinal cord injury	1
806.24	T1 -T6 level with other specified spinal cord injury	3
806.26	T7 -T12 level with complete lesion of cord	9
806.29	T7 -T12 level with other specified spinal cord injury	2
806.4	Lumbar, closed	11
	Subtotal	97
Trauma To The Spinal Cord Without Evidence Of Spinal Bone Injury		
952.01	C1 -C4 level with complete lesion of spinal cord	3
952.04	C1 -C4 level with other specified spinal cord injury	2
952.05	C5 -C7 level with unspecified spinal cord injury	1
952.06	C5 -C7 level with complete lesion of spinal cord	2
952.08	C5 -C7 level with central cord syndrome	4
952.09	C5 -C7 level with other specified spinal cord injury	6
952.16	T7 -T12 level with complete lesion of spinal cord	2
	Subtotal	20
	TOTAL	117

Factors associated with spinal cord injury-logistic regression results

As presented in Table 5, results of the univariate logistic regression analysis suggest that the following factors are associated with spinal cord injury among drivers injured in serious but initially survivable passenger vehicle MVC: driving a pickup truck, being ejected from the vehicle, being involved in a rollover collision, single vehicle collisions, single vehicle rollovers, not wearing a seatbelt, collisions on rural roadways and being resident of a rural area. According to the univariate models, there are no important associations between the occurrence of spinal cord injuries among drivers and sex and age of the driver. As well, neither the time of day nor day of week appear to be associated with the occurrence of spinal cord injuries among drivers injured in serious car crashes.

Table 5. Univariate Logistic Regression Results Describing Factors Associated with Occurrence of Spinal Cord Injuries Among Seriously Injured Drivers

	β	Standard Error (β)	Crude Odds Ratio	95% Confidence Interval
Sex				
Females (reference)				
Males	0.344	0.229	1.41	0.90-2.21
Age				
Age in years	-	0.005	0.99	0.98-1.00
Aged 20 and older(reference)	0.007	0.271	0.99	0.57- 1.71
Aged 19 and under	0.007			
Type of Vehicle				
Car/Van/S.U.V. (reference)				
Pickup Truck	0.629	0.199	1.87	1.27-2.77
Ejected From Vehicle				
Not Ejected (reference)				
Ejected	0.514	0.215	1.67	1.10-2.55
Type of Collision				
Not a Rollover (reference)				
Rollover	1.687	0.209	5.40	3.58-8.15
Multiple vehicle crash (reference)	1.804	0.231	6.07	3.86-9.55
Single vehicle crash				
Not a single vehicle rollover (reference)	1.881	0.210	6.56	4.31-10.00
Single vehicle rollover				
Seatbelt Use				
Wearing a seatbelt (reference)	0.595	0.200	1.81	1.22-2.68
Not wearing seatbelt				
Type of Roadway				
Not a rural roadway (reference)	1.650	0.370	5.20	2.51-10.75
Rural roadway/highway				
Address				
Urban resident (reference)				
Rural resident	1.007	0.234	2.73	1.72-4.33
Day of Week				
Not on the weekend (reference)	0.222	0.210	1.29	0.84- 1.97
Weekend				
Time of Day				
Between 6 am and 11:59 pm (reference)	0.281	0.224	1.32	0.85-2.10
After Midnight				

The adjusted odds ratios for the association between the explanatory factors and the occurrence of spinal cord injury among drivers hospitalized for serious injuries are presented in Table 6. This analysis suggests that when the effects of type of vehicle, use of seatbelts, ejection status and place of residence, age and sex are accounted for, drivers who were injured in a single vehicle rollover collision were more likely to experience spinal cord injury (adjusted O.R. 6.59 95% C.I. 4.00-10.85). Table 6 also shows that driving a pick-up truck, not wearing a seatbelt and living in a rural area are not independently associated with a greater risk of spinal cord injury in a serious car crash, when the influences of the other explanatory factors are controlled for.

Table 6. Multivariable Logistic Regression Results Describing Factors Associated with Occurrence of Spinal Cord Injuries among seriously injured drivers (n= 1580)

	β	Standard Error (β)	Adjusted Odds Ratio*	95% Confidence Interval
Type of Collision				
Not a single vehicle rollover (reference)	1.886	0.255	6.59	4.00-10.85
Single vehicle rollover				
Ejected From Vehicle				
Not Ejected (reference)				
Ejected	0.520	0.239	1.68	1.05 – 2.68
Type of Roadway				
Not a rural roadway (reference)	0.660	0.408	2.00	0.91-4.30
Rural roadway/highway				
Type of Vehicle				
Car/Van/S.U.V. (reference)	0.14	0.214	1.16	0.76-1.75
Pickup Truck				
Seatbelt Use				
Wearing a seatbelt (reference)	0.327	0.252	1.38	0.85-2.27
Not wearing seatbelt				
Address				
Urban resident (reference)	0.417	0.290	1.52	0.86 -2.67
Rural resident				
Sex				
Females (reference)				
Males	0.049	0.255	1.05	0.637-1.73
Age				
Age in years	0.004	0.006	1.00	0.99-1.017

Overall Wald statistic= 106.768,d.f.,7, p=<0.000. * Adjusted for the effects of all other factors in the model .

Stratified Analysis- Drivers Ejected And Not Ejected From The Vehicle

When the effects of all the other variables in the model are taken into account, drivers who were ejected from a vehicle were more likely to be hospitalized for spinal cord injury. For the variable "ejected" it was suspected that there was an interaction

effect, but testing for a first order interaction between ejection status and single vehicle rollover collisions yielded a non-significant result. However, due to the findings of the literature review and the clinical importance of whether or not a driver remained inside the vehicle during the crash, the data was stratified according to ejection status and two models were fitted.

There were 345 drivers documented as being ejected from the vehicle in the course of the crash of which 339 had complete data and were included in the model. Among drivers ejected from the vehicle, the odds of ending up with a spinal cord injury are increased by a factor of thirteen (OR 13.06, 95% CI 1.76 – 96.87) when drivers are in a single vehicle rollover compared to other types of collisions (Table 7). The wide confidence interval makes this result difficult to interpret. The width of this confidence interval is related to small cell size – there was only 1 driver in the spinal cord injury group who was ejected who was not involved in a single vehicle rollover collision.

Of the 1,391 drivers who remained inside the vehicle during their car crash, 1,245 had complete data and were included in the model. When this strata of drivers is examined, being in a single vehicle rollover collision increased the odds of a spinal cord injury by a factor of seven (OR 7.61, 95% CI 4.79 – 12.14).

Table 7. Stratified Analysis: Logistic Regression Results Describing Factors Associated with Occurrence of Spinal Cord Injury

	β	Standard Error (β)	Odds Ratio	95% Confidence Interval
Drivers Ejected from Vehicle (n=339)				
Type of Collision				
Not a Single vehicle Rollover over (reference)				
Single Vehicle Rollover	2.570	1.022	13.06	1.76– 96.87
Drivers Not Ejected from Vehicle (n=1408)				
Type of Collision				
Not a Single Vehicle Rollover (reference)				
Single Vehicle Rollover	2.031	0.238	7.61	4.79 – 12.14

Factors Associated with Single vehicle Rollovers

There were 556 single vehicle rollover collisions among the 1,753 drivers injured in serious crashes. The adjusted odds ratios for factors associated with the occurrence of single vehicle rollover collisions among drivers hospitalized for serious injuries are presented in Table 8. When the effects of age, vehicle type, place of residence and roadway are adjusted for, male drivers are almost twice as likely as females to be involved in a single vehicle rollover collision (adjusted OR 1.55, 95% CI 1.16-2.07). Table 8 also shows that younger drivers, males, driving a pick-up truck, and driving on rural roadways and highways are independently associated with a greater risk of involvement in single vehicle rollover collisions, when the influences of the other explanatory factors are controlled.

Table 8. Multivariable Logistic Regression Results Describing Factors Associated With Occurrence Of Single Vehicle Rollover Collisions (N= 1753)

	β	Standard Error (β)	Adjusted * Odds Ratio	95% Confidence Interval
Sex				
Females (reference)				
Males	0.488	0.127	1.62	1.27 – 2.08
Type of vehicle				
Car/Van/S.U.V (reference)				
Pick-up truck	0.560	0.119	1.75	1.38- 2.21
Type of Roadway				
Not a Rural Roadway (reference)				
Rural Roadway	1.035	0.167	2.03	2.03 – 3.9
Age in years	-0.022	0.004	0.97	0.97-0.99

* Adjusted for the effects of all other factors in the model.

Chapter 5. Discussion

Serious crashes that result in hospitalization for spinal cord injury do not occur at random. They are associated with specific characteristics. This study shows that the typical profile of drivers who sustain spinal cord injury as a result of motor vehicle collisions are males involved in a single vehicle rollover collision on a rural roadway. More than 60% of all cases of spinal cord injury among drivers in this study fit this description. This study found that single vehicle rollover collisions are strongly associated with the occurrence of spinal cord injury among drivers admitted to hospital. Of all the potential explanatory factors studied, single vehicle rollover collisions are the most highly associated with the occurrence of spinal cord injuries among drivers of passenger vehicles. For drivers who were ejected, after adjusting for gender, seatbelt use, type of roadway and place of residence, single vehicle rollovers increased the odds of a spinal cord injury by a factor of twelve. Among drivers who remained in the vehicle throughout the crash, single vehicle rollovers are associated with a six fold increase in the odds of suffering a spinal cord injury.

Single vehicle rollover crashes occur as a result of the interactions between driver, road, vehicle, and environmental factors. Single vehicle rollover collisions occur when the driver loses control of the vehicle and are associated with unsafe and reckless driving behaviors (NHTSA, 2002; Insurance Institute for Highway Safety, 2002). In some cases the occurrence of the crash which produced the spinal cord injury was primarily the product of choices the driver made while driving. For example, perhaps the driver was traveling too fast for the road or weather conditions and lost control of the vehicle due to excessive speed. Alternatively, the vehicle may have been traveling within the posted

speed limits but the driver may have been inebriated and was unable to control the vehicle. Both of these scenarios could result in a permanent tragedy – loss of sensation and movement- for a moments worth of poor judgment, haste or inattention.

The trauma registry uses built in memo fields to add circumstantial information about car crashes. When this information is available from the crash and first responder reports, it is collected into the trauma registry. An examination of the narrative memo fields of car crashes that resulted in spinal cord injuries reveals several important themes: speeding, road conditions and field reports of apparently intoxicated drivers.

The data clearly shows that the majority of single vehicle rollover crashes that result in spinal cord injury to the driver occurred on rural roadways and highways. Barring vehicle failure, the reasons that drivers lose control and crash on these types of roadways are largely under the control of the driver. Thus, a large proportion of the crashes on rural roadways and highways were potentially preventable by better driving habits. There is evidence that excessive speed (speeds greater then 20 kph above the posted limit) is an important contributory factor in 25% and 20% of fatal and serious crashes respectively (NHTSA, 2002). Extrapolating from this, perhaps as many as 30 drivers with spinal cord injury would not have the injury had they simply driven more slowly.

It has been suggested that the rate of serious head and neck injuries increases for crashes occurring at speeds above 80 km/h (Tolonen, 1986). This effect was demonstrated in Finland when a temporary maximum speed limit of 80 km/hr was imposed on the population. During the period of the speed restriction, traffic fatalities decreased by 44% (Tolonen, 1986). While the speed at which the driver was traveling is

not a piece of information that is systematically captured by trauma registries, an examination of the memo fields shows that excessive speed was frequently ascribed to the rollover collisions on rural roadways and highways. However, most of rural Alberta is sparsely populated and hard to police due to the vast geographic area. Under the circumstances, active strategies, such as enforcement of speed limits, are not a viable way to prevent these crashes.

Certain types of passenger vehicles, namely sport utility vehicles and pick-up trucks, are more prone to rollover than other classes of vehicles. The estimated risk of rollover differs by vehicle type: 13 percent of cars and 14 percent of vans in police-reported single-vehicle crashes rolled over, compared to 24 percent of pickup trucks and 30 percent of sport utility vehicles (NHTSA, 2002). In addition to being more likely to roll than other passenger vehicles, fatality Analysis Reporting System data shows that in 1997, the single-vehicle rollover fatality rate for sport utility vehicles was almost five times the fatality rate of sedan type passenger vehicles (NHTSA, 2002). Whether or not drivers of sport utility vehicles are more likely to suffer a spinal cord injury was not a factor that could be assessed in this study. The limitation of the data set available for this study precluded identification of sport utility vehicles as a distinct category of passenger vehicle as only pick-up trucks are categorized separately from other passenger vehicles.

A study that compared pick-up truck driver-owners and drivers who owned only sedan type cars determined that pickup truck owners reported lower restraint use, more risky driving behaviors, and had more traffic citations (Anderson, 1999). Other data have shown that after accounting for the effects of driver age and gender, roadway alignment and surface condition, and whether or not the crash occurred in a rural area, light trucks

are twice as likely as cars to experience rollovers (Farmer, 2002). The present study found a two-fold increase in the crude odds of spinal cord injury for drivers of pick-up trucks. However, no significant association remained after adjusting for other factors. This study result may be due to the inclusion of sport utility vehicles in the 'other vehicle category". Inclusion of sport utility vehicles in the same group as sedan type cars and then using this as the referent group calculate the odds ratio for risk associated with driving a pick-up truck likely produced a biased estimate of association. Specifically, the risk associated with pick up trucks was probably underestimated. Future research into factors associated with spinal cord injuries during serious motor vehicle collisions should have separate categories for sedan, sport utility vehicles and pick-up trucks. This may be particularly important for places similar to Alberta given the high proportion of pick-up trucks on the road.

Of the 92 drivers with spinal cord injury who were involved in a single vehicle rollover collision, only 40% wore a seatbelt. Studies clearly demonstrate the protective effects of seatbelt use among passengers involved in serious car crashes (Heulke, 1981; Hadley, 1985; Anderson, 1990; Kaplan,1991; Sasso, 1997). This body of literature appears to be conclusive evidence that, overall, seatbelts are effective in reducing spinal cord injuries and deaths from car crashes. However, there is also a body of literature, comprised largely of case studies, that suggests that certain types of injuries, including cervical and other spinal cord injuries, may be associated with seatbelts worn under certain conditions in some types of serious car crashes (Heulke, 1975; Bilo, 1979; Heulke, 1995).

Was seatbelt non-use a factor in spinal cord injuries among drivers? The findings from the present study clearly show a low rate of seatbelt use among seriously injured (non-case) drivers and an even lower rate among drivers with spinal cord injury. Involvement in a serious car crash while not wearing a seatbelt almost doubled the risk of hospitalization for spinal cord injury. Seatbelt use prevented ejection from the vehicle in all but one driver injured in a serious crash. The findings from this study regarding factors associated with not wearing a seatbelt – younger drivers, males and rural dwellers- are similar to findings from other studies (Lerner, 2001; Transport Canada, 2001).

Results from Transport Canada's July 2001 survey of seatbelt use in Canada showed that while 89.9% of Canadians are wearing their seatbelts, only 84.9% of Albertans are (Transport Canada, 2001). The gap is even more striking for rural dwelling Albertans and Albertans who drive pick-up trucks (69% and 67% seatbelt use rates respectively) (Transport Canada, 2001). Given the associations between single vehicle rollover collisions on rural roadways, pick-up trucks, male drivers and spinal cord injuries, it would appear that drivers most at risk of spinal cord injury are the least likely to wear a seatbelt.

In study after study, pre-injury use of alcohol has been shown to increase the risk of motor vehicle collisions (Andersen,1990; Stoduto, 1993; Shibata, 1994; Borgialli, 2000; Sommers, 2000). Originally, at the outset of this study, data regarding pre-injury alcohol use (as measured by blood alcohol tests upon admission to trauma center) was sought. It was hypothesized that pre-injury alcohol use would be a factor in crashes that result in spinal cord injury among drivers. However, in this series of 1735 patients, only

35% of drivers were tested for alcohol use upon admission to trauma centers in Alberta. Therefore, assessment of pre-injury alcohol use as a potential explanatory factor was not possible. This is a troubling finding as it is widely acknowledged that knowledge of alcohol use is important in the care of trauma patients. The Trauma Association of Canada mandates the measurement of blood alcohol concentration for all trauma patients aged 12 years and older. In the present study, the rate of testing for alcohol use among patients admitted to trauma centers in Alberta is much lower than the rates seen in North American trauma centers (Soderstrom, 1994; Canadian Institute for Health Information, 2001).

When the memo field narrative data was examined for drivers with spinal cord injury, alcohol use was documented on the patient care record for 25 drivers who did not have a blood alcohol concentration measured upon admission to a trauma center. Future researchers may want to explore the reasons why blood alcohol concentrations are not done in Alberta's trauma centers.

Accurate, valid and complete data are needed to evaluate potential explanatory factors in epidemiological studies of trauma and injury. Many variables are important in passenger vehicle crashes that result in spinal cord injuries among drivers. Data from trauma registries has been a valuable source of information for many investigations of injuries resulting from motor vehicle collisions and other causes (Woodruff, 1994; Nayduch, 1994; McLellan, 1996; Forst, 1999; Jurkovich, 1999; Wynn, 2002). A systematic review of the adequacy of trauma registry data for use in research concluded that trauma registries are a valid useful source of data for retrospective studies of the epidemiology of serious injury and the effectiveness of trauma programs (Jurkovich,

1999). Other authors do not support this contention and seriously question the use of retrospective trauma registry data because of data deficiencies such as invalid or miscoded data and the fact that trauma registries are not population based datasets (Osler, 1997; Owen, 1999). Despite the fact that the Alberta Trauma Registry has collected data for seven years, the validity of trauma data from the provincial trauma registry used in this study has not been evaluated. Alberta follows the trauma registry guidelines set out by the Canadian National Trauma Registry. Alberta's trauma registry is very similar to Ontario's registry, which has been used extensively in all forms of trauma research.

Trauma registries are an incomplete source of information regarding motor vehicle collisions and use of data from trauma registries can lead to biased results. The external validity of studies that use trauma registries is compromised by the narrow scope of injury data available from registries. For example, among the six provinces that contribute to the national trauma registry a standardized approach is used to collect data on patients with ISS scores of 12 or more. It is estimated that this represents only 8 to 12% of all injured patients. The results of this study can only be generalized to drivers involved in car crashes that result in serious (Injury Severity Score >=12) injuries.

In several ways, the results of this study are likely to be influenced by selection bias. For example, although the four centers that participate in the trauma registry have complete ascertainment of spinal cord injuries, the database used has incomplete ascertainment of seriously injured non-cases. This may have biased the estimates of association and degree of risk. It is possible that this study may have underestimated the associations because the nominators for factors for the seriously injured non-cases are smaller than they should be (due to missing cases).

Conclusions

This study indicates that single vehicle rollover collisions are strongly associated with the occurrence of spinal cord injuries after a passenger vehicle collision. Single vehicle rollover collisions are more common among males, pickup truck drivers and on rural roadways. Testing for pre-injury alcohol use is infrequently done among drivers admitted to trauma centers in Alberta.

Recommendations

1. Trauma centers should add the following information to data collected by trauma registries: year, make and model of the vehicle; velocity at impact; number of passengers in the vehicle at time of collision; conditions and type of rural roadway.
2. The trauma registry should separate vehicle type into the following categories: sedan type cars, vans, sport utility vehicles and pick up trucks.
3. Trauma centers in Alberta need to implement strategies to ensure that every driver has a blood alcohol level measured and documented upon admission.
4. A formal assessment of the validity, accuracy and reliability of data in the Alberta trauma registry should be undertaken and published.
5. Effective methods of preventing single vehicle rollover collisions should be sought. Populations most at risk such as males, rural dwellers and those who routinely travel on rural roadways should be targeted for these intervention programs.

References

Anderson PA, FP Rivara,Maier RV. Drake C. The epidemiology of seatbelt-associated injuries. J Trauma. 1991;31: 60-7.

Anderson CL, Winn DG, Agran PF. Differences between pickup truck and automobile driver-owners. Accid Anal Prev. 1999;31:67-76.

Andersen, J. A., B. A. McLellan, Pagliarello G, Nelson WR. The relative influence of alcohol and seatbelt usage on severity of injury from motor vehicle crashes. J Trauma. 1990;30: 415-7.

Association for the Advancement of Automotive Medicine. The Abbreviated Injury Scale, 1990 Revision. (Association for the Advancement of Automotive Medicine, Des Plaines, IL.)1990. p. 15-24.

Baker SP, O'Neill B, Haddon W, Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma. 1974;14:3 187-96.

Baker SP, O'Neill B. The injury severity score: an update. J Trauma. 1976;16:11 882-5.

Bilo HJ, van Vuuren ZC. Ayptical lumbar spine injury from a two-point seatbelt. J Trauma. 1979 19:11 841-5.

Bourbeau R, Desjardins D, Maag U, Laberge-Nadeau C. Neck injuries among belted and unbelted occupants of the front seat of cars. J Trauma.1993;35:794-9.

Borgialli DA, Hill EM, Maio RF, Compton CP, Gregor MA. Effects of alcohol on the geographic variation of driver fatalities in motor vehicle crashes. Acad Emerg Med. 2000;7:1 7-13

Boyd CR, Tolson MA, Copes WS . Evaluating trauma care: the TRISS method. Trauma Score and the Injury Severity Score. J Trauma.1987;27:4 370-8.

Bracken MB,Freeman DH, Hellenbrand K. Incidence of acute traumatic hospitalized spinal cord injury in the United States, 1970-1977. Am J Epidemiology.1981;113:615-22.

Burney RE, Maio RF, Maynard F, Karunas R. Incidence, characteristics, and outcome of spinal cord injury at trauma centers in North America. Arch Surg.1993;128:596-9.

Canadian Institute of Health Information. Spinal cord related admissions for injuries resulting in paraplegia or quadraplegia by age group and sex 1994/95-1998/99. (October 2002) (http://secure.cihi.ca/cihiweb/en/media_11Apr2001_tab_5_ehtml.)

Canadian Paraplegic Association. Spinal cord injury in Canada. (October 27, 2000) http://www.canparaplegic.org/national/level2.tpl

Centers for Disease Control. Acute traumatic spinal cord injury surveillance- United States 1987. MMWR CDC. 1988; 37:285-86.

Connor J, Norton R, Ameratunga S, Robinson E, Civil I, Dunn R, Bailey J, Jackson R. Driver sleepiness and risk of serious injury to car occupants: population based case control study. BMJ.2002;324:1125

Cushman LA, Good RG, States JD. Characteristics of motor vehicle accidents resulting in spinal cord injury. Accid Anal Prev.1991;23:557-60.

Danesh JN, Dixon GS. Epidemiology of spinal cord injury. N Z Med J.1991;104:915 295-6.

Demetriades D, Charalambides K, Chahwan S, Hanpeter D, Alo K, Velmahos G, Murray J, Asensio J. Nonskeletal cervical spine injuries: epidemiology and diagnostic pitfalls. J Trauma.2000;48:724-7.

Dixon GS, Danesh JN, Cardoc-Davies TH. Epidemiology of spinal cord injury in New Zealand. Neuroepidemiology.1993;12:88-95.

Dryden DM, Saunders LD, BH Rowe, May LA, Yiannakoulias N, Svenson L, Schopflocher D, Voaklander DC. Identification of traumatic spinal cord injuries in Alberta, Canada. Ann Epidemiol.2002; 12:527-528.

Farmer CM, Lund AK .Rollover risk of cars and light trucks after accounting for driver and environmental factors.Accid Anal Prev.2002;34:163-73.

Finnerup NB, Johannesen IL, Sindrup SH, Bach FW, Jensen TS. Pain and dysesthesia in patients with spinal cord injury: A postal survey. Spinal Cord.2001;39:5 256-62.

Forst LS, Hryhorczuk D, Jaros M. A state trauma registry as a tool for occupational injury surveillance. J Occup Environ Med.1999; 41:514-20.

Foss RD, Beirness DJ, Sprattler K. Seat belt use among drinking drivers in Minnesota.Am J Public Health. 1994;84:1732-7.

Goldberg J. Gelfand HM, Levy PS. An evaluation of the Illinois trauma registry: the completeness of reporting. Med Carel,1980;18:520-31.

Gongora E, Acosta JA, Wang DS, Brandenburg K, Jablonski K, Jordan MH. Analysis of motor vehicle ejection victims admitted to a level I trauma center. J Trauma.2001;51:854-9.

Griffin MR, Opitz JL, Kurland LT, Ebersold MJ, O_Fallon WM. Traumatic spinal cord injury in Olmsted County, Minnesota, 1935-1981. Am J Epidemiol.1985;121: 884-95.

Hadley MN, Sonntag VK, Grahm TW, Masferrer R, Browner C. Axis fractures resulting from motor vehicle accidents. The need for occupant restraints. Spine.1986;9: 861-4.

Health Care Financing Administration. International Classification of Diseases, 9th Revision, Clinical Modification, 3rd edition. US Department of Health and Human Services. 1989 Washington D.C.

Holly LT, Kelly DF, Counelis GJ, Blinman T, McArthur DL, Cryer HG. Cervical spine trauma associated with moderate and severe head injury: incidence, risk factors, and injury characteristics. J Neurosurg.2002;96:285-91.

Hosmer D.W., Lemeshow S. (1989) Applied Logistic Regression. New York. John Wiley and Sons.

Huelke DF, Kaufer H. Vertebral column injuries and seat belts.J Trauma.1975;15:4 304-18.

Huelke D F, J. O'Day J, Mendelhson RA. Cervical injuries suffered in automobile crashes. J Neurosurgery. 981;54:316-22.

Huelke DF, Mackay GM, Morris A, Bradford M. A review of cervical fractures and fracture-dislocations without head impacts sustained by restrained occupants. Accid Anal Prev.1993;25:731-43.

Huelke DF, Mackay GM, Morris A. Vertebral column injuries and lap-shoulder belts. J Trauma.1995;38:547-56.

Insurance Institute for Highway Safety, 2002.http://www.highwaysafety.org/safety_facts/fatality_facts/teenagers.pdf

Jurkovich GJ, Mock C. Systematic Review of Trauma System Effectiveness Based on Registry Comparisons. J Trauma.1999;47:S46-S55.

Kaplan BH, Cowley RA. Seatbelt effectiveness and cost of noncompliance among drivers admitted to a trauma center. Am J Emerg Med.1991;9:4-10

Kramer C F, Thode HC. Adequacy of hospital discharge data for determining trauma morbidity patterns. J Trauma.1995; 39: 935-40.

Krause JF, Franti CE, Riggins RS. Neurologic outcome and vehicle and crash factors in motor vehicle related spinal cord injuries. Nueroepidemiology.1982:1; 223-38.

Laapotti S, Keskinen E.Differences in fatal loss-of-control accidents between young male and female drivers.Accid Anal Prev.1998; 30:435-42.

Lerner EB, Jehle DV, Billittier AJ, Moscati RM, Connery CM, Stiller G. The influence of demographic factors on seatbelt use by adults injured in motor vehicle crashes. J Accid Anal Prev.2001;33:5 659-62.

Long WB, Sacco WJ, Copes WS, Lawnick MM, Proctor SM, Sacco JB . An evaluation of expert human and automated Abbreviated Injury Scale and ICD-9-CM injury coding. J Trauma.1994;4:499-503.

Mackenzie EJ, Siegel JH, Shapiro S, Moody M, Smith RT. Functional recovery and medical costs of trauma: an analysis by type and severity of injury. J Trauma.1986; 28:3 281-97.

Mao Y, Zhang J, Robbins G, Clarke K, Lam M, Pickett W. Factors affecting the severity of motor vehicle traffic crashes involving young drivers in Ontario. Inj Prev.1997;3:183-9

McLellan BA. A Canadian National Trauma Registry: The time is now. J Trauma. 1997;42:5;763-68.

McLellan BA Rizoli SB, Brenneman FD, Boulanger BR, Sharkey PW, Szalai JP. Injury Pattern and Severity in Lateral Motor Vehicle Collisions A Canadian Experience. J Trauma.1996;41:708-713.

National Highway Traffic Safety Administration. Presidential Initiative for Increasing Seat Belt use Nationwide. America's Experience with Seatbelt and Child Seat Use. (October, 2002).
http://www.nhtsa.dot.gov/people/injury/airbags/presbelt/america_seatbelt.html

National Highway Traffic Safety Administration 2002:http://www.nhtsa.dot.gov/ cars/rules/ rulings/Rollover/Chapt02.html).

National Academy of Science National Research Council. Accidental Death and Disability: The Neglected Disease of Modern Society. Washington D.C. Division of medical Sciences, National Academy of Science National Research Council; April 1969.

Norris FH, Matthews BA, Riad JK Characterological, situational, and behavioral risk factors for motor vehicle accidents: a prospective examination. Accid Anal Prev. 2000;32:505-15

O'Connor P. Incidence and patterns of spinal cord injury in Australia. Accid Anal Prev. 2002; 34: 405-415.

O'Connor P. Injury to the spinal cord in motor vehicle traffic crashes.Accid Anal Prev. 2002;34:477-85.

Orsay EM, Turnbull TL, Dunne M, Barrett JA, Langenberg P, Orsay CP. Prospective study of the effect of safety belts on morbidity and health care costs in motor-vehicle accidents. JAMA.1988;260:3598-603.

Osler TM, Cohen M, Rogers FB, Camp L, Rutledge R, Shackford SR. Trauma registry injury coding is superfluous: a comparison of outcome prediction based on trauma registry International Classification of Diseases-Ninth Revision (ICD-9) and hospital information system ICD-9 codes.J Trauma.1997;43:2 253-6.

Ostrom M, Sjogren H, Eriksson A. Role of alcohol in traffic crashes involving women: passenger car fatalities in northern Sweden. J Stud Alcohol.1995;5: 506-12.

Owen JL, Bolenbaucher RM, Moore ML.Trauma registry databases: a comparison of data abstraction, interpretation, and entry at two level I trauma centers.J Trauma.1999;46:6 1100-4

Peduzzi P, Cocata J, Feinstein A, Holford TR. The importance of events per independent variable (EPV) in proportional hazards regression analysis. II. Accuracy and precision of regression estimates. J Clin Epidemiol.1995;48:1503-1510.

Perneger T, Smith GS. The driver's role in fatal two-car crashes: a paired "case-control" study. Am J Epidemiol.1991;134:1138-45

Pollock DA, McCain PW. Report from the 1988 trauma registry workshop, including recommendations for hospital-based trauma registries. J Trauma.1989;29:827-34.

Porter R S, Zhao N. Patterns of injury in belted and unbelted individuals presenting to a trauma center after motor vehicle crash: seat belt syndrome revisited. Ann Emerg Med.1998;32: 418-24.

Price, C., S. Makintubee, Epidemiology of traumatic spinal cord injury and acute hospitalization and rehabilitation charges for spinal cord injuries in Oklahoma, 1988-1990. American Journal of Epidemiology 1994;139:37-47.

Ravenscroft A, Ahmed YS, Burnside IG. Chronic pain after SCI. A patient survey. Spinal Cord 2000 38:611-4.

Sasso R C, Meyer PR, Heinemann AW, Van Aken J, Hastie B. Seat-belt use and relation to neurologic injury in motor vehicle crashes. J Spinal Disorders 1997;10: 325-8.

Sekhon LH, Fehlings MG. Epidemiology, demographics, and pathophysiology of acute spinal cord injury. Spine 2001;26:S2-12.

Shibata A, Fukuda K. Risk factors of fatality in motor vehicle traffic accidents. Accid Anal Prev 1994 26:3 391-7.

Soderstrom CA, Dailey JT, Kerns TJ. Alcohol and other drugs: an assessment of testing and clinical practices in US trauma centers. J Trauma. 1994;36:68-73.

Sommers MS, Dyehouse JM, Howe SR, Lemmink J, Davis K, McCarthy M, Russell AC. Attribution of injury to alcohol involvement in young adults seriously injured in alcohol-related motor vehicle crashes. Am J Crit Care 2000 ;9: 28-35

Statistics Canada, 2002 http://www.statcan.ca/english/Pgdb/demo02.htm

Stoduto G, Vingilis E, Kapur BM, Sheu WJ, McLellan BA, Liban CB. Alcohol and drug use among motor vehicle collision victims admitted to a regional trauma unit: demographic, injury, and crash characteristics. Accid Anal Prev 1993 Aug 25:4 411-20

Stover SL, Fine PR .The epidemiology and economics of spinal cord injury. Paraplegia 1987; 25:225-8.

Tator CH, Duncan EG, Edmonds VE, Lapczak LI, Andrews DF. Changes in epidemiology of acute spinal cord injury from 1947 to 1981. Surg Neurol 1993; 40: 207-15.

Tavris DR, Kuhn EM, Layde PM. Age and gender patterns in motor vehicle crash injuries: importance of type of crash and occupant role. Accid Anal Prev 2001; 33:167-72.

Thurman DJ, Burnett CL, Jeppson L, Beaudoin DE, Sniezek JE. Surveillance of spinal cord injuries in Utah, USA. Paraplegia 1994;32: 665-9

Thurman DJ, Burnett CL, Jeppson L, Beaudoin DE, Sniezek JE. Risk factors and mechanisms of occurrence in motor-vehicle related spinal cord injuries in Utah. Accid Anal Prev 1994 ;27:411-5.

Tolonen J, Santavirta S, Kiviluoto O, Lindqvist C. Fatal cervical spinal injuries in road traffic accidents. Injury 1986 17:154-8.

Trauma Association of Canada. Trauma system accreditation guidelines. 1993.

Traffic Safety Facts 1998. Washington DC. National Highway and Traffic Safety Administration; 1999.

Transport Canada, 2001. Results of Transport Canada's June 1999 Survey of Seat Belt Use in Canada http://www.tc.gc.ca/roadsafety/stats/cl9907/en/sb99sm_e.htm#Light.

Treacy PJ, Jones K, Mansfield C. Flipped out of control: single-vehicle rollover accidents in the Northern Territory. Med J Aust 2002;176: 260-3.

United States Census Bureau, 2003 http://www.census.gov/main/www/cen2000.html

Waller JA. Reflections on half a century of injury control. Am J Pub Health. 1994. 84;4. 664-670.

Wigglesworth EC. Motor vehicle crashes and spinal injury. Paraplegia 1992; 30: 543-9.

Woodruff BA, Baron RC. A description of nonfatal spinal cord injury using a hospital-based registry. Am J Prev Med 1994 10: 10-4.

Young W, Keck SWM, Keck. Spinal Cord Injury Levels and Classification. Center for Collaborative Neuroscience. Rutgers University, Piscataway, NJ.(April 11 2002) (http://carecure.rutgers.edu/spinewire/articles/spinallevels.html)

Appendix I

Health Research Ethics Board biomedical research health research
2J2.27 Walter Mackenzie Centre, University of Alberta, Edmonton, Alberta T6G 2B7
3-48 Corbett Hall, University of Alberta, Edmonton, Alberta T6G 2G4

UNIVERSITY OF ALBERTA HEALTH SCIENCES FACULTIES, CAPITAL HEALTH AUTHORITY, AND CARITAS HEALTH GROUP

HEALTH RESEARCH ETHICS APPROVAL

Date:	October 2002
Name of Applicant:	Dr Linda Carroll & Ms. Diane Kirwin
Organization:	University of Alberta
Department:	Public Health Sciences
Project Title:	Risk Factors for Spinal Cord Injuries Among Drivers

The Health Research Ethics Board (HREB) has reviewed the protocol for this project and found it to be acceptable within the limitations of human experimentation. The HREB has also reviewed and approved the subject information letter and consent form.

The deliberations of the HREB included all elements described in Section 50 of the *Health Information Act*, and found the study to be in compliance with all the applicable requirements of the Act. The HREB determined that obtaining consent for the disclosure of the health information to be used in the research from the individuals who are the subjects of the information would not be reasonable, feasible, or practical given the retrospective nature of the study.

The approval for the study as presented is valid for one year. It may be extended following completion of the yearly report form. Any proposed changes to the study must be submitted to the Health Research Ethics Board for approval. Written notification must be sent to the HREB when the project is complete or terminated.

Dr. Sharon Warren
Chair of the Health Research Ethics Board (B: Health Research)

File number: B-220702-PHS

University of Alberta Capital Health CARITAS HEALTH GROUP